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NEDU TR 02-07
JULY 2002

SURVEY OF CURRENT BEST PRACTICES FOR DIVING IN CONTAMINATED WATER

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NAVAL SEA SYSTEMS COMMAND
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SURVEY OF CURRENT BEST PRACTICES FOR DIVING IN CONTAMINATED WATER

INTRODUCTION

The Navy Experimental Diving Unit (NEDU) conducted a worldwide survey of commercial, governmental, and military diving organizations to provide guidelines for U.S. Navy divers operating in contaminated water. This survey attempted to identify the current best practices and equipment for diving in contaminated water, including personal protective equipment as well as hazard identification, diver training, and decontamination practices. This survey was conducted via telephone interviews and followed a script of questions (Appendix A) developed with input from experienced divers and Diving Medical Officers at NEDU. Survey participants are listed in Appendix B.

Commercial survey participants were selected through Internet-based searches for operators advertising that they performed contaminated water diving operations and through referrals from Ross Saxon, Ph.D., President of the Association of Diving Contractors. Domestic government agencies were selected because of their involvement with diving in contaminated water. International Navy and governmental contacts were limited, mainly because NAVSEA had recently requested and received information about diving in contaminated water from a variety of international agencies. The majority of these responses were general in nature.

Most participants reported contaminated water diving in sewer operations. Some reported missions were in industrial sites — holding ponds, cooling tanks, etc. Few respondents reported having nuclear power plant diving experience.

The report on this survey makes every attempt to ensure that summarized responses closely represent the intents of respondents. No editorial corrections were made to their responses. Reported facts, regulations, and recommendations in publications to which responses allude have not been verified.

EQUIPMENT

Most operators plan for "worst case scenarios" when they expect to confront contamination in the water. Their aim in selecting equipment is to sequester the diver from the water as completely as possible.

Helmets

SuperLite 17B and 27 — Usually configured with double exhaust kit, this demand regulator helmet is currently employed by the U.S. Navy for contaminated water diving. A manufacturer's representative recommends adjusting the "dial-a-breath" on the regulator to minimize negative pressure inside the helmet, so that minimal inspiratory effort is required to initiate a breath. Theoretically, negative pressure within the helmet could create a gradient affording an opportunity for contaminated water to enter.

Several respondents complained of leaks or reflux of fluids — often correlated with much particulate matter in the water — through the double exhaust system. One respondent observed that material seemed to preclude a tight seal by becoming wedged under the lip of the valves. One operator reported using the Gas Miser return system, which allows all exhaust to flow to the surface and thus eliminate possible regurgitation of water through the exhaust system, with the SuperLite helmet.

DESCO Airhat — Often called a "pot" or referred to as the Max-Gene-Nohl, this is a "free-flow," positive pressure helmet fitted with a double exhaust. Many respondents deemed this helmet the "driest," with no reported leaks, and one respondent called this system "the most reliable exhaust." Many operators reported using the SuperLite system for "dirty" water but relied on the DESCO if the water was "really dirty." One respondent reported that the "best available" system was the DESCO pot fitted with a return-line system. Complaints about this system focused mainly on the noise associated with its free flow of air. Some European governments have limited the use of free-flow helmets due to a concern for hearing damage.

Aquadyne, **Comex**, **AH-3B**, and **Miller Hats (400)** — Various respondents mentioned these helmets, but provided few details. One Australian operator reported successfully using a (proprietary) triple exhaust system configured for the **Aquadyne** helmet: arranging the exhaust valves at acute angles to one another apparently limits the reflux of fluid.

DSI Band Mask 18 — One operator reported using this, with a neoprene hood, for some contaminated water diving. A NATO-member Navy also reported using full face masks, but it reported using the **AH-3B** for contamination considered "more severe." Environmental Protection Agency (EPA) divers from one region were reported to wear **AGA** masks for diving in contaminated water. One manufacturer's representative, however, specifically discourages using its full face mask for protection from contaminated water, a position shared by many respondents who felt that full face masks, even in free-flow mode, are prone to at least minimal leaking. Additionally, such masks neither protect the ears nor limit dermal exposure for much of the head/neck.

Lama — A French respondent reported diving in radiologically contaminated water with this free-flow (2 mbar overpressure) polycarbonate "bubble helmet." Ease in cleaning and detachable helmet weights that significantly limit diver fatigue during the decontamination phase were among advantages reported with this helmet. However, its polymer is apparently optically active: each eye of the diver views a slightly different image, a difference commonly resulting in reports of motion sickness. Also, this helmet was reported as being used to depths of 17 meters, but since divers using it have no direct access to the nose for middle ear equilibration, how fast they may descend for deeper dives is unknown.

General comments on helmets: Some respondents reported success in absorbing refluxed water by using cotton gauze in a double exhaust system. Using Mylar

speakers allows helmets to be more thoroughly soaked and cleaned without concern for damage after contaminated dives.

Dry Suits

Viking HD — This vulcanized rubber dry suit with helmet-specific mating neck dam, along with the **Gates Pro HD 1500**, was widely reported as being used for diving in contaminated water. One respondent called the **Yokohama 12 Bolt** (now reported to be the **Gates Breast Plate**) the "driest" suit, primarily because it lacks a zipper or exhaust valve, both of which are commonly reported sources of leaks and decontamination difficulty. A commonly reported "completely dry" system included a free-flow helmet with a vulcanized dry suit configured in an "open rig" setup: that is, the buoyancy of the suit was controlled not from an intrinsic air supply to it, but rather from airflow in the helmet via open communication through the neck.

One operator reported using a hot-water suit — with its continuous flow of hot water in a layer between the diver's skin and the suit's interior — for diving in contaminated water. A shortcoming of this system is that if the water supply is interrupted, the lack of this water flow in the suit allows ingress of contaminated water. This respondent's standard operating procedure (SOP) included immediately aborting the dive if water flow terminated.

General comments on suits: One respondent reported employing single-use dry suits for diving in radiologically contaminated water. For suit exhaust valves, the chest-mounted position works better than the shoulder to keep the diver from becoming entangled with gear or obstacles. Inner tube patches bonded to the knees and elbows increase the use life of dry suits. Zipper pull-tabs often become snagged; they should be removed, and use a wire through the slot to open/close the zipper. Several operators reported using disposable Tyvek oversuits to add protection and significantly decrease decontamination time. Using bib overalls for chafing protection was also reported. Rubber galoshes and haz-mat booties were used when added foot protection was deemed necessary.

Gloves

Playtex kitchen gloves — Multiple operators reported using widely available disposable gloves, which appeared to provide a good balance between protection and dexterity. Most respondents reported using a double gloving technique with rubber surgical or fabric gloves as inner protection; they specifically described taping gloves (with duct tape) to suit sleeves and securing them with outer locking rings in accordance with Viking instructions. However, one respondent reported better success with **Calpico** tape (plumber's tape) than with duct tape. He also reported using Calpico tape on umbilicals to permit greater ease in cleaning than that afforded by duct tape. Depending on the nature of the tasks to be completed, some respondents reported using mesh or Kevlar over gloves for added physical protection. One commercial Australian respondent reported using plastic kitchen wrap around glove/sleeve junctions for added watertightness. Several operators reported that their divers used barrier

creams — either lanolin or petroleum based — on their hands and forearms before they donned protective gear.

GENERAL EQUIPMENT COMMENTS

A repeated sentiment from survey respondents was that a good working condition of protective equipment was vital to sequester divers from hazardous environments. No operator reported specific criteria for servicing or discarding equipment used in contaminated water diving. All indicated compliance with industry standards for maintaining equipment generally, with much major servicing occurring at annual intervals. Because of increased stresses on equipment used for diving in contaminated water and the potentially increased risk of exposure if the equipment failed, most respondents reported increased maintenance beyond that recommended by manufacturers or by industry organizations. The range of maintenance practices varied from servicing/replacing some equipment before each mission to using an "eyeball" inspection method to service equipment when deterioration could be visually ascertained.

Calpico tape and tie wraps, rather than duct tape, were both recommended to secure umbilicals, mainly for ease in cleaning them. Rubber harnesses were also suggested as being easier to clean than more commonplace web-strapping ones.

Equipment Failures

Many respondents reported some water residue within protective rigs after dives; the number and extent of leaks they reported were directly proportional to the work efforts of the divers. Failure sites included dry suit seams (especially in the stride of the garment), neck and wrist cuff seals, and exhaust valves. Exhaust valves on the helmets, especially on the SuperLite, were reported as failure points for water leakage, a report correlated not only with diver effort/positioning but also with the amount of particulate matter suspended in the water. Yet some respondents were adamant that they were able to dive "completely dry," especially with a free-flow helmet mated to an open-rig dry suit. They surmised that any water within the rig after diving resulted from condensation and/or perspiration.

Thermal Concerns

Most of the protective gear used to dive in contaminated water creates thermal stress in what may otherwise be euthermic conditions. Anecdotally, diving with a dry suit in water temperatures greater than 80 °F can significantly affect diver performance as well as effective working time and can result in heat injury. Several operators reported using ice vests and ice packs within the helmets to mitigate thermal effects. One respondent reported using an oversuit that was supplied with circulating chilled water. Divers and tenders were offered additional breaks and rotated through work cycles at an increased rate during thermally stressful conditions. A French respondent reported monitoring

divers' heart rates and using tachycardia as a surrogate for hyperthermia and as a criterion for terminating a dive.

Another technique reported to be successful in precluding thermal stress was to use a **Coretech** cooling undersuit, a dive skin worn under the drysuit and designed with a network of small tubes running through it. Supplied by a surface cooler containing ice/water, these tubes transport chilled water next to the diver's skin. One operator reported completing multiple dives at temperatures greater than 120 °F with this suit. He also reported one dive profile of three hours at 130 °F with no diver complaints of thermal stress.

Most operators minimized concerns about thermal stress among tenders. One respondent did report placing a "soaker" hose supplied with fresh water over the standby diver's shoulders to mitigate his thermal stress.

PRACTICES AND PROCEDURES

PROCEDURES

No standardized procedures to analyze water for potential contaminants or to assess risks related to such analyses were reported. Most operators reported relying on customers/clients to characterize contaminants. Many respondents reported employing a "common sense" approach, in which they often used their greatest protective posture when diving in sewer ponds or industrial sites. When contaminant data was available, some respondents reported using permeability information from suit and helmet manufacturers to decide whether or not to dive. They reported that they lacked this information for umbilicals, gloves, and other ancillary equipment. Basing his decisions about diving on a "happy medium" of available permeability information, one operator reported limiting all contaminated dives to 150 minutes. Another respondent reported not diving in river water when local authorities had closed recreational beaches subsequent to rain, and then resuming operations when the beaches were "opened".

Regulations

A Canadian respondent reported diving in compliance with the **Ontario Ministry of Labor, Part 11**, which addresses diving in contaminated water. Another NATO-member Navy respondent reported using decontamination procedures outlined in the **Allied Tech Publication 55** regarding nuclear, biological, and chemical warfare decontamination.

For general safety concerns, most domestic commercial operators reported that they complied strictly with ADC Consensus standards. However, all respondents specifically denied that any guidelines or regulations existed for diving in contaminated water. One respondent did refer to the confined space requirements that the Occupational Safety and Health Administration (OSHA) has established for testing for H_2S, LEL, NO_2 and CO levels as well as specific requirements for entering sewer systems.

Another operator reported abiding by "Site Safety Plans" that the U.S. Coast Guard provides mainly for hazard sequestration and decontamination. The respondent reported that these plans did not cover testing water or assessing exposure risks.

Dangerous Diving

Some operators reported that a variety of chemical hazards — such as concentrated acids, cyanide, and hydrogen sulfide — would preclude them from attempting to dive. The rationale they gave was that, if divers were to become exposed, these hazards were considered life threatening, and since the operators could not guarantee that no breach of their protective gear would occur, they would not dive.

Several operators reported that they considered using remote operated vehicles (ROVs) for such missions. One respondent reported relying on "immediately dangerous to life and health" (IDLH) characterizations of chemicals reported in *the North American Emergency Response Guidebook* and the *NIOSH Pocket Guide to Chemical Hazards* to decide whether or not to dive. Also, another operator reported that, even though he deemed his cooling system capable of mitigating thermal stress, he did not consider diving in water exceeding 200 °F because of concerns about drysuit delamination.

Decontamination

A wide variety of decontamination procedures were reported. Most operators reported employing an internal method without specific regulatory guidance. Some reported that they operate as directed by the OSHA Hazardous Materials Procedures outlined in **29 CFR 1910.120**, which reportedly offers guidance about site safety plans including zones of varied contamination.

All respondents reported following this general sequence for decontaminating divers as they come out of the water:

--Washing down the diver with high-pressure fresh water (to remove bulk debris/contamination) as he emerges from the surface.
--Cutting off the outer suit (if the diver has used one).
--Scrubbing the diver with long-handled brushes and a "soapy" solution, and taking care to focus on areas where debris may be lodged — i.e., around fittings, under cuffs, and especially around the neck dam.
--Undressing the diver, recleaning the gear, and having the diver shower. One Australian operator reported that he required divers to clean under their fingernails and rinse their mouths with mouthwash. He added that he also prohibited divers from having long hair, because he felt it increased the difficulty of effectively decontaminating them.
--Soaking umbilicals and all ancillary equipment — e.g., harnesses, emergency gas supply bottle, etc.

Decontamination methods varied, depending on the operator and on the contaminant involved. One respondent reported using recommendations of the Center for Disease Control (CDC) for decontaminating biohazardous materials after diving in sewage treatment water. A variety of surfactants and soaps were also reported: Betadine, Hibiclens, Tide, "industrial grade" Lysol, Greased Lightening (reported to be "rubber friendly"), Simple Green, and Clorox. One respondent reported that the Clorox manufacturer recommends using this product when it is less than two weeks old for decontamination purposes: apparently, its efficacy as a decontaminant decreases significantly with age. Many respondents reported using Simple Green, which had purported antibiological activity and which they found to be effective in dispersing greasy substances. One respondent reported using Listerine to wash his mouthpiece/regulator apparatus between uses by different divers.

Many operators reported their needs to capture the effluent from decontamination procedures. One method reported by several respondents was to have the diver stand in a child's wading pool while being washed: the pool captured effluent for disposition as hazardous waste.

Tenders

Protection for dive tenders was focused primarily at splash protection. Several respondents reported that tenders, outfitted in Tyvek protective suits or impermeable rain gear, were required to wear eye protection — either goggles or a full face shield — at all times. Only one operator reported needing to have his tenders wear cartridge respirators. Another operator who employed respiratory precautions outfitted tenders with compressed air-supplied AGA masks: major benefits of using these, he reported, were increased comfort for the tenders and the ability to have voice communications.

Compressed Air

Several operators reported using a "common sense" approach in deciding to use bottle compressed or site air. All respondents reported using bottled compressed air that had been compressed remotely if any air contamination was suspected on site. For workers employing compressors on site, the respondents reported taking care to ensure that the intake was upwind from the contamination and site that moisture and particulates were filtered. An Australian operator reported using an additional filter pack composed of silica gel and activated carbon with a gauze filter to decrease the likelihood of contaminants entering his air supply. The only air testing reported was that done in routine fashion per regulation, usually on a biannual cycle. Many respondents reported aborting a dive immediately if their air began to "taste or smell bad."

Training

A strong majority of respondents reported that all divers working in contaminated water had received forty hours of hazardous materials training. In many instances, they reported that this was included in commercial diver training school. Most respondents reported giving divers additional internal training programs for work in contaminated water, training that included protective equipment use, in-water procedures, and decontamination methods. Two respondents reported that they required employees diving in sewers or for body recovery to receive OSHA bloodborne pathogens training. One respondent reported that he directed full-scale drills with mock decontamination, and endorsed this training as vital to success in conducting diving operations in contaminated water.

Medical

All respondents reported requiring divers to undergo routine annual medical examinations in order to comply with ADC recommendation or government regulation. Medical tests in these exams included blood tests, urinalyses, and often pulmonary function studies. Most American diving companies in this survey reported that they required divers to receive immunizations for hepatitis A and B. An Australian operator reported that he required his divers to receive tetanus, polio, and diphtheria immunizations (which are given as routine preventive care for children in many countries) in addition to these.

In addition, most respondents reported that they would refer divers for medical care on an as-needed basis whenever those divers suffered any trauma during a contaminated dive. Because of concerns about increased risk of infection and complications, respondents referred for care even divers with seemingly inconsequential lacerations. One operator referred to medical surveillance recommendations made in OSHA 29 CFR 1910.120 for personnel exposed to hazardous materials, but he was unable to recall specific details during the interview.

The concept of completing dives requiring surface decompression in contaminated water also comprises a medical concern. To complete surface decompression, the time for transition from being in the water to undergoing recompression in the hyperbaric chamber ordinarily should be minimized: U.S. Navy guidelines stipulate less than five minutes. This time limitation creates a significant challenge for contaminated diving operations. In order to perform thorough decontamination, most respondents reported spending between 15 and 20 minutes to complete each diver's decontamination procedures. One respondent reported that he preferred to complete shallow saturation dives in lieu of dive profiles requiring surface decompression if he were diving in contaminated water.

CONCLUSION

All respondents described well-organized plans for completing dive missions in contaminated water. However, many voiced concerns for the dearth of information about the identification of hazards and the risks associated with exposure to them. The respondents often operate by using a precautionary principle of offering their divers the maximum protection available when they have a reasonable suspicion that hazards are present.

APPENDIX A

SURVEY QUESTIONS FOR CONTAMINATED WATER DIVING (CWD)

1. What types of standard diving equipment do you use for routine diving operations?

2. How do you adjust your standard equipment for CWD ops?

   - Any retrofits from standard gear?
   - Any increase in pre/post-dive maintenance?
   - Any increased manning requirements due to heat/fatigue associated with wearing protective equipment?
   - Do you have any procedures to mitigate thermal effects?
   - Which type of gloves do you use?

3. Which equipment failures are common?

   Swollen gaskets, degraded suits, etc?

   - How do you manage total failures-e.g. flood outs, etc.
   - How have you overcome these shortcomings?
   - If a dive goes as planned and equipment functions as expected, is it still common for divers to experience some contact with the water—i.e. swallow some water, find residual in dry suit, boots, etc.

4. How do you routinely identify if a dive site is contaminated?

   - How do you assure any site is non-contaminated?
   - Do you perform any site water sampling for chemical/biological hazard testing?
   - Do you usually rely on the client?
   - How do you select appropriate testing facility and which tests?
   - How do test results affect your procedures?
   - Do you change dive schedule based on weather, i.e.—no coastal diving after rain due to influx of hazards from runoff?

5. Do you perform CWD ops in radiologically contaminated areas?

   - If so, how do you change your procedures from those employed in chem/bio contamination?

6. What rules/guidelines govern your contaminated water procedures—EPA, NIOSH, or all internal?

7. Are there situations you would consider too contaminated in which to dive?

8. What are your decontamination procedures?

   - Your decontamination solutions?

9. What precautions are offered tenders?

   - Do you have protective garments and respirators available to them?
   - Do you increase manning due to thermal stress/fatigue of the tenders?

10. Any increased filtering or surveillance of site compressed air?

11. Do you have increased medical surveillance for divers involved in CWD ops?

12. Do you have a formalized training program for your CWD operations?

APPENDIX B

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